LIFE HISTORY STUDIES

The Atlantic Surf Clam

Introduction

Collections of the Atlantic surf clam began in February 1972 for the spat and in April 1972 for adults and juveniles. The spatial and temporal distribution, number per m^2, monthly length-frequency distribution, and monthly reproductive condition were determined for samples taken in 1974.

Materials and Methods

The Atlantic surf clam was collected in the ocean and Inlet with the clam dredge and ponar grab. Anterior-posterior lengths of specimens less than 10 mm were measured to the nearest 0.1 mm with an ocular micrometer. Lengths of large specimens (greater than 10 mm) were measured to the nearest mm with a vernier caliper.

Gonad condition was estimated monthly by macroscopic examination of a random subsample of 10 to 35 clams (60-169 mm in length) from one collection in the ocean and one in the Inlet.

Results

Spat, which were collected with the ponar grab, ranged from 0.5 to 24.4 mm in size (Table 64). They ranked fifth by numerical abundance in ocean (8% of all specimens of all species) and Inlet (4%) collections. They ranked twelfth by weight (4% of total weight) at the Site and third (3%) in the Inlet (zone 1010).

Most spat were collected in spring and about half of those were collected in May when bottom water temperatures were 9.0 to 14.5 C. The modal size class was 1.0-1.4 mm in April and May, and was 3.5-3.9 mm in June. Spat were common in the summer, especially in July when the size distribution was bimodal (1.0-1.4 mm and 11.5-11.9 mm). Few spat were collected from August through October but density increased slightly in November and was high in the winter, particularly in January. Bottom water temperatures from November through March decreased from 14.0 to 2.0 C.

Spat were abundant at all ocean stations and averaged 152 n/m^2 for the year. Densities were highest at stations within 1.5 nautical miles of shore where they averaged 160 n/m^2 for the year. The station with the highest average abundance (465 n/m^2) was located just north of the Site (zone 5143).

Specimens of the Atlantic surf clam collected with the clam dredge ranged in size from 15 to 169 mm. They ranked first in numerical abundance in the ocean (70% of all specimens of all species) and second in the Inlet (5%). They ranked first by weight in the ocean (94% of the total weight) and Inlet (64%).

Small specimens of the surf clam (15 to 99 mm) and commercial sized surf clam (100 to 169 mm) were collected with a clam dredge. Small clams were most abundant in August when their modal size class was 30-34 mm. In September, small clams taken in the clam dredge survey were most common near shoals just off Little Egg and Brigantine inlets at depths between 12 and 18 feet. Some 94% of these were taken at depths less than 20 ft. Their modal size class was 25-29 mm with a second mode at 30-34 mm. In November, the modal size class was 45-49 mm.

Small clams from the ocean (less than 60 mm) comprised 64% of those taken in August, 5% in September, 2% in October, and 48% in December. They comprised less than 2% of those collected during the rest of the year. The Landward II station (zone 5158) yielded the most.

Approximately 77% of the clams taken on the Site transects were of commercial size (100 mm or greater). In Little Egg Inlet, at the station east of Stake "96", 58% of the clams were commercial size. No seasonal changes in the abundance of commercial sized clams were evident (Tables 65 and 66).

The abundance of those clams collected with the clam dredge varied spatially. The densest aggregation was in Little Egg Inlet east of Stake "96" where the average yearly density was 3.25 n/m^2. Another dense aggregation existed at the ocean station nearest shore (zone 5158) where the average yearly density was 0.69 n/m^2. For survey stations inshore of the 20 ft depth contour the average density was 0.51 n/m^2. Between the 20 and 50 ft contours it was 0.18 n/m^2.

Gonadal condition of those clams collected in the ocean during April indicated that 90% were full (ripe) and 10% were partly spent. Most gonads were partly spent from June through September. In October, all clams appeared spent. From November through March, when bottom water temperatures decreased from 14.0 to 2.0 C, most of the gonads were refilling.

In the Inlet, 100% of the surf clam gonads were full in April. From May through August, most were partly spent and from September through January most were spent. In February and March, gonads were refilling. Evidence from gonad condition indicated that spawning occurred between mid-April and mid-May. It was difficult to detect the second spawn by gonad condition; however, the abundance of spat in late fall and winter indicated that a second spawn occurred.

Discussion

Commercial sized Atlantic surf clam showed no seasonal trends in abundance. About 77% of the specimens taken in the ocean were 100 mm or greater. Densities ranged from 0.69 to 0 n/m^2 in the ocean. In the Inlet (zone 1010 near "G" buoy), where densities reached 3.25 n/m^2, only 58% of the specimens were of commercial size.

Maturation of the gonads of clams collected in the ocean and Inlet appeared to be similar. In the present study, gonads appeared to be ripening at temperatures from 2 to 14 C. Ropes (1968) reported that a progressive development of gonads to a ripe state occurred prior to the first annual spawn during a period of warming of temperatures to 12 C.

The major spawn in the ocean and Inlet occurred between mid-April and mid-May. The largest density of spat was in May and a second peak in abundance occurred between November and March. Ropes (1968) reported that a major midyear spawn and a minor late year spawn occurred in New Jersey in 3 out of the 4 years he studied. He stated that the late year spawn was not always an annual event.

Some trends in spatial distribution of spat were evident. Very few settled in the Inlet although adult clams were abundant there. Most settled in the ocean within 1.5 nautical miles offshore.

Small specimens of the Atlantic surf clam (between 15 and 60 mm in length) were most abundant in August and November at the stations nearest shore. About 33% of the clams taken throughout the year at stations sampled monthly were less than 100 mm in length.

Rock Crab

Introduction

The rock crab was common throughout 1974 in the ocean and bays in the vicinity of Little Egg Inlet. Life history information for 1973 was briefly discussed by Garlo et al. (1974). The objectives of the present study were to determine its spatial and temporal distribution, abundance, size, migration, sex ratio, and time of molting.

Materials and Methods

The rock crab was taken by trawl, clam dredge, lobster pot, ponar grab, 0.5-m plankton net, 0.1-m^2 Bongo, and 12.5-cm Clarke-Bumpus plankton sampler. Collections were usually made at least once a month throughout the year. Few collections were made in December. No lobster pot samples were taken in September, November, or December.

Results

A total of 4,971 rock crab was collected in 1974. Most (83.5%) were taken in the ocean; some (16.5%) were collected in the bays and

Inlet (Table 67). Trawl collections captured 78.6%, lobster pot 12.1%, ponar grab 7.8%, and clam dredge 1.5% of those taken in the ocean (Table 68). In the bays and Inlet, trawl samples yielded 67.3% of those rock crab taken and clam dredge samples took 32.7% (Table 69).

Most were collected in the summer (42.6% of the total) and fewer were taken in the winter (21.6%), spring (19.5%), and fall (16.3%). Most collected in the ocean were taken in summer (48.2%) while most of those taken in the bays and Inlet were collected in winter (57.6%). The largest number per collection (n/coll.) taken by 25-ft trawl in the ocean was 28.7 n/coll. (summer) and in the bays and Inlet it was 31.0 n/coll. (winter).

Carapace width of 2,983 rock crab collected by 25-ft trawl was measured (Tables 70 and 71). The mean size from January through April was 78 mm for those collected in the ocean and 74 mm for those taken in the bays and Inlet. Mean size decreased to 21 mm (ocean) and 27 mm (bays and Inlet) from May through October and increased to 45 mm (ocean) and 66 mm (bays and Inlet) from November through December (Fig. 28).

The inshore-offshore migration of larger individuals was associated with seasonal changes in water temperatures. Mean bottom temperatures at the Site ranged from 4.6 C in January to 8.0 C in April, the period when the largest crabs were abundant. Small specimens were collected from May through October. Mean bottom temperatures were 12.1 C in May and 15.9 C in October. Mean temperatures ranged from 11.6 C in November to 6.0 C in December when larger crabs returned to the area.

The male-female ratio was 2,825:1,336 (2.1:1) for pooled data, from all stations sampled (Table 72). In the ocean, males dominated with a ratio of 7.3:1 in winter and 7.5:1 in spring. In summer and fall, the ratio was less than 2:1. In the bays and Inlet, males dominated with a ratio of 2.7:1 in winter and 5.1:1 in fall. In spring and summer, the ratio was less than 2:1. A ratio dominated by males was found for rock crab off the Virginia Coast by Shotton (1973).

The size range of males was 4-138 mm while females ranged from 3-91 mm. Shotton (1973) also found that males grew to a significantly larger size than females.

After copulation, sperm plugs (hard, rod-like crystalline bodies) extend into the vagina and protrude from the vulvae. They are an indication that mating has occurred (Terretta 1973). Females with sperm plugs ranged from 18 to 78 mm in size and were found throughout the year. Most plugged females appeared in the bays and Inlet in winter and spring, and in the ocean in summer and fall. Few were taken in spring when the number of gravid females was the largest.

Gravid females were collected in all months except July and August and were most common in spring. They ranged in size from 22 to 77 mm. Most gravid females were found in the bays and Inlet during winter and spring, and in the ocean during fall.

The rock crab was recorded as molting only if its shell was in a soft condition. Molting was most prevalent among juveniles in July, when they molted several times. Most adults molted in January.

Rock crab zoeae were present at the Site from early April to early June, and their maximum density was in May. Zoeae were collected 8.0 nautical miles off Little Egg Inlet from late March to early July (no sample was taken in April) with the greatest density in early June.

Rock crab megalopae were found at the Site from early to mid-June and in September. Megalopae were taken 8.0 nautical miles off Little Egg Inlet from early June to early August; the greatest density was in early June.

Juvenile rock crab (3-9 mm) appeared in the ocean in June and July. The modal size class was 5-9 mm in June, 10-14 mm in July, and 20-24 mm in August.

Discussion

The rock crab was a year-round resident in the study area. Larger individuals moved inshore from November throgh April during the period of cold water temperatures. Shotton (1973) hypothesized that the rock crab followed colder waters during seasonal inshore-offshore migrations along the Virginia coast. The rock crab is most abundant in the Chesapeake Bight at water temperatures from 4 to 8 C (Musick and McEachran 1972). For most of the year, at least twice as many males were collected as females.

A small plugged female (18 mm) and gravid female (22 mm) suggested that the rock crab reached sexual maturity early. The largest number of plugged females (25.9 mm, mean size) occurred in September. The mean size of females in September was 24.3 mm, which indicated that the rock crab matures in its first year. Shotton (1973) collected a 28.2 mm ovigerous female and other ovigerous specimens less than 33 mm. It was found to be immature at a size less than 60 mm in the Gulf of Maine (Krouse 1972) and in the Gulf of St. Lawrence (Scarratt and Lowe 1972). In this study it matured earlier and grew faster than its northern counterparts.

PROTOPLANKTON

James H. Currie

Introduction

The major objective of the protoplankton study was to quantitatively determine the temporal distribution of the standing crop at the Site. At least one sample each month, from May 1972 through April 1973, was quantified. Monthly fluctuations in the abundance of the major groups throughout the year are discussed.

Materials and Methods

Descriptions of the study area, sampling program, and laboratory methods were presented by Currie (1974). Sampling extended through May 1974 in the bays and was terminated in October 1974 in the ocean. Samples collected during 1974 have not been analyzed.

All samples for analysis were concentrated by sedimentation in the original collection jars. The supernatant was removed by slow siphoning. Enumerations of protoplankters were carried out in both the Sedgwick-Rafter and Palmer-Maloney chambers, following the procedures outlined previously by Currie (1974). Small aliquots from 15-cm nannoplankton net (10-μm mesh) samples were also examined qualitatively for the presence of large, rare protoplankters.

Results

The following results include only those obtained since the last progress report by Currie (1974).

The standing crop at the Site was determined for single collection dates in May, June, and July of 1972 and in February, March, and April of 1973. Six out of the seven major groups were generally present in all samples analyzed (Tables 73-78). Silicoflagellates were absent in May, and in March ciliates were absent. Total protoplankton density ranged from 327,040 cells/liter in July to 1,823,330 cells/liter in June.

Diatoms

From May through July, 1972, diatom density at the surface averaged only about 4,200 cells/liter. Densities were greater from February through April, 1973, with a peak of about 248,700 cells/liter in February. *Thalassiosira nordenskioldii* was dominant in February and March. *Rhizosolenia fragilissima* dominated in April and was subdominant in February. The number of species in the 6 month period was the lowest in May and June and the largest in February and April.

Dinoflagellates

Dinoflagellates were most abundant in May and June of 1972, with a peak of approximately 239,700 cells/liter in June. Densities during the remaining months were all under 3,000 cells/liter. The number of species was lowest in March and largest in June. *Ceratium* species, particularly *C. minutum* and *C. bucephalum*, dominated in June. Two unidentified gymnodinians were together numerically most important at this time.

Other Protoplankters

Non-motile chlorophyte densities were moderately low from May to July 1972 and from February to April 1973, and averaged approximately 9,300 cells/liter. Blue-greens were always abundant; densities ranged from 198,200 cells/liter in July to 859,700 cells/liter in June. Naked flagellate densities ranged from 23,400 cells/liter in April to more than 131,000 cells/liter in June. Euglenoids were present in June and July 1972, and in April 1973. Silicoflagellate numbers were always low, and densities never exceeded 420 cells/liter. Tintinnids were the predominant ciliates and a peak abundance of approximately 15,000 cells/liter occurred in May and June.

Discussion

Protoplankton abundance at the Site from May 1972 through April 1973 is discussed below. Cell densities of the major groups enumerated in all surface collections which were analyzed to date are given in Table 79. Total protoplankton densities are also indicated.

Total protoplankton abundance reached a maximum of approximately 1.8 million cells/liter in June. Secondary peaks in abundance of about 1.4 to 1.5 million cells/liter also occurred in late August and late September, 1972.

As a group, diatoms exhibited maximum abundance in late September 1972 (over 826,000 cells/liter) and they comprised about 54% of the total protoplankton standing crop. Dominant species included Skeletonema costatum, Thalassiosira rotula, and T. condensata. Possible causes for this bloom of diatoms were discussed by Currie (1974).

A secondary peak in diatom abundance occurred in February 1973. Cell density totaled over 248,700 cells/liter and they comprised 25% of the total protoplankton abundance. Thalassiosira nordenskioldii was the dominant species and Rhizosolenia fragilissima and Skeletonema costatum were subdominants.

Thalassiosira species were reported by Sage and Herman (1972) to predominate during a late February bloom in Sandy Hook Bay. Studies by Riley (1967) and Riley and Conover (1967) in Long Island Sound extended over several years and indicated that the main diatom flowerings occurred between late January and mid-March. They reported that the dominant species in late-winter blooms were the diatoms Skeletonema costatum and Thalassiosira nordenskioldii. Both Skeletonema costatum and Rhizosolenia fragilissima were reported as dominants during a winter-spring bloom in Chesapeake Bay (Smayda 1973).

Light and temperature were the primary factors affecting the initiation of the winter bloom (Riley 1967). Experiments have shown that T. nordenskioldii may have a competitive advantage over S. costatum during periods of low temperatures (2-3 C) and lowered light intensities (Riley and Conover 1967, Smayda 1973). At the Site, T. nordenskioldii was dominant over S. castatum in February when the surface water temperature was 1.5 C.

According to Riley and Conover (1967) nutrients may also affect species succession and abundance. In the present study, surface nitrate plus nitrite concentrations (2.68 μg at N/1) in February were intermediate for the year as a whole, but the silicate value (10.93 μg at Si/1) represented the maximum for the year (see Currie 1974). The presence of a very high silicate concentration suggested that the February sampling date was coincident with an early stage of the winter diatom bloom. The silicate concentration (0.81 μg at Si/1) at the time of the mid-March collections was the lowest recorded for the year. Total diatom density at this time had declined to a relatively low level (22,500 cells/liter), indicating that the winter bloom period was completed.

Peaks in dinoflagellate abundance occurred in June and late August 1972 (239,710 and 384,390 cells/liter respectively). In June, they comprised about 13% of the total standing crop and in late August, more than 27%. Several unidentified peridinians collectively were dominant in June. *Ceratium minutum* was a subdominant. In late August, dinoflagellate populations were dominated by two unidentified gymnodinians and three species of *Prorocentrum*. *Prorocentrum micans* was dominant, and comprised approximately 48% of the total dinoflagellate standing crop. The other important species of *Prorocentrum* were *P. scutellum* and *P. triangulatum*.

Dinoflagellates have been reported as abundant during the summer in Chesapeake Bay, Long Island Sound, Raritan Bay, and the western part of Sandy Hook Bay (Kawamura 1966, Riley and Conover 1967, Smayda 1973). *Ceratium minutum* was reported by Martin (1929) to be "common in ocean plankton" in New Jersey. *Prorocentrum micans* was a late summer dominant in Raritan Bay and was prominant throughout the summer in Chesapeake Bay (see Smayda 1973). A discussion of some of the environmental factors affecting dinoflagellate abundance in the present study was presented by Currie (1974).

Among the other protoplankton groups, silicoflagellates were always rare. The maximum density was approximately 1,800 cells/liter in late August. Distephanus speculum and Ebria tripartita were the most prevalent species. Small coccoid blue-greens were always abundant, and ranged in density from 170,000 cells/liter in December 1972 to 859,700 cells/liter in June 1972. Non-motile green algae ranged from 4,720 cells/liter in May 1972 to 37,370 cells/liter in early August. None of these three groups exhibited any definite seasonal trends in abundance. Naked flagellate numbers were the lowest in April 1973 (23,400 cells/liter) and the highest during August 1972 (mean of 293,000 cells/liter); densities were higher during the warmer months. Ciliates were dominanted in most instances by the tintinnids. Maximum abundance (more than 14,400 cells/liter) of the latter occurred during May and June, 1972.

ZOOPLANKTON

Phillip H. Sandine and Felicia A. Swiecicki

Introduction

Collections were taken throughout the year to determine the temporal and spatial distribution and species composition of zooplankton in the study area. Three stations north and offshore of the study area were sampled to evaluate the extent of the estuarine zone (as defined by by Smith 1966) beyond Little Egg Inlet.

Materials and Methods

Six ocean stations and six bay stations were sampled in 1974 (Table 80). Three ocean stations, located 6 to 11 nautical miles north and offshore of the study area, were added in 1974.

Bay collections were taken monthly with a Clarke-Bumpus sampler (#20 net) from January through October. No collections were taken in November and December. Oblique tows, and occasionally an additional surface tow were taken at bay stations.

Collections in the ocean were taken as follows: (1) the Site was sampled once in January and December and twice monthly from February through November; (2) Landward of the Site and Seaward of the Ridge stations were sampled once in January and May through November, and twice monthly from February through April; (3) stations offshore and north of the study area were sampled monthly in March and May through November. Oblique tows were made with a Clarke-Bumpus sampler (#20 net) at all ocean stations. Tows were replicated routinely at the Site, but only occasionally at the other stations. Replicates were taken consecutively rather than simultaneously. Surface and bottom tows were also made at the Site.

Monthly night collections were taken at the Site in June, July, September, and October near or at a new moon. Surface, bottom, and oblique tows were taken at sunset and 2 and 4 hours afterward.

Early in the year the standard size Clarke-Bumpus plankton net (85 cm) was replaced with a longer one (130 cm) to reduce clogging. The longer net was of a cylindrical-cone design. Collections taken during April and May with both nets were compared and results were similar.

Immediately after collection, samples were preserved in 5% buffered formalin. In the laboratory, samples were concentrated to a volume of 50 to 350 ml. A 1-ml subsample was taken from a thoroughly mixed sample with a Stempel pipette and placed in a Sedgwick-Rafter chamber. A minimum of two subsamples was taken. Zooplankters were enumerated using a compound microscope. A zooplankter was classified as common if its density exceeded $1{,}000/m^3$ and abundant if it exceeded $10{,}000/m^3$.

Macrozooplankton was collected with 1.0-m and 0.5-m plankton nets and a $0.1\text{-}m^2$ Bongo. All nets had a mesh size of 0.5-mm. From January through March, simultaneous surface (1.0-m net), midwater, and bottom tows (0.5-m nets) were taken twice a month at the Site. In March, replicate 3-step oblique tows (surface, midwater, and bottom) were made with a 0.5-m net at the station offshore of Little Egg Inlet. From April through November, oblique tows ($0.1\text{-}m^2$ Bongo) were taken twice a month at the Site and once a month at the stations north and offshore of the study area. Surface and bottom tows (0.5-m net) were taken twice monthly at the Site. Night collections of macrozooplankton were also taken at the Site.

Immediately after collection macrozooplankton samples were preserved in 5% formalin. In the laboratory, the entire sample was examined grossly in a shallow tray. Macroforms were identified and total counts made except in samples where they were abundant. For enumeration of abundant forms, a 1/2 or 1/4 subsample was taken with a Folsom Plankton Splitter, subsampled with a 10-ml Stempel pipette, and enumerated microscopically. From 2 to 4 counts were made and averaged. A macrozooplankter was classified as common when its density exceeded $10/m^3$ and abundant if it exceeded $100/m^3$).

Zooplankters were identified to the lowest taxa possible and are listed in Table 81. Keys for many meroplankters (primarily larval forms) are inadequate or lacking. All densities are recorded as number per m^3 (n/m^3) and are from oblique collections unless stated otherwise.

Zooplankters were catagorized as one of the following: (1) "estuarine and marine"; (2) "euryhaline marine" or: (3) "stenohaline marine". The classification is that of Jeffries (1967) and the terms are defined in the Glossary.

Friedman's test (Tate and Clelland 1957) was used to determine if zooplankton densities differed between stations ($P \lesssim .05$).

Results and Discussion

Clarke-Bumpus Collections

Data from bay and ocean collections made with a Clarke-Bumpus are presented in Appendix Tables 24 to 29 and Appendix Tables 30 to 35, respectively. Densities of zooplankton for ocean and bay collections are given in Tables 82 to 83. The average monthly densities of zooplankton at the Site are shown in Fig. 30.

Copepods

At the Site copepods (adults and copepodites) and copepod nauplii were the dominant forms collected during the year except in May when meroplankton predominated. Maximum densities of copepods ($77,471/m^3$) and copepod nauplii ($74,347/m^3$) were observed in early and mid-November, respectively. Harpacticoids were the dominant copepods during November (Appendix Table 31).

In the bays, copepods and copepod nauplii dominated all collections except for the May collection at Brigantine Bays #1 when meroplankton predominated (Table 83). The maximum average monthly density of copepods ($63,483/m^3$) was observed in July; Great Bay #3 had the greatest density ($136,373/m^3$). *Acartia tonsa* was the dominant species in July. The generally low densities of copepods in the bays in August apparently resulted from predation by the ctenophore, *Mnemiopsis leidyi*.

At ocean stations, densities of copepod nauplii dropped below that of copepods primarily during late summer and fall, a period when two small species (Oithona brevicornis and Paracalanus crassirostris) were dominant (Fig. 30). Because the early naupliar stages of these forms can readily pass through a #20 net, naupliar values reported are more conservative for that period. The similar drop in nauplii values was observed in 1973. This pattern was not as obvious in the bays where the larger form, Acartia tonsa, was usually the summer/fall dominant.

The average yearly density of nauplii exceeded that of copepods at all stations except Mullica River #1 (M.R. #1) and offshore of Brant Beach (Table 83 and Fig. 30). These two locations may not be optimal for reproduction of the dominant copepod species found in this study.

Average monthly copepod densities showed no significant difference between the Site and stations north and offshore of the study area (n= 8 collections) or between bay stations (n=10). Important differences at the species level are discussed below.

Acartia clausi, an "estuarine and marine" form, was taken in the bays from January through June (Table 84). It was generally absent at bay stations until October, except for a bottom collection at Little Egg Inlet in early July. At ocean stations, it was taken from February through July, with one additional occurrence in September (Table 84). Its maximum density for bay and ocean stations was $46,029/m^3$ (early April) and $2,276/m^3$ (late June), respectively.

Densities of A. clausi at the Site and landward of the Site were similar to those found at Little Egg Inlet. Seaward of the Site and north and offshore of the study area, densities were usually substantially lower than those at the Site. A. clausi appeared in greater densities and for a longer period at the Site in 1974 than in 1973.

Acartia tonsa was found in the bays year-round, but at very low densities during winter months (Table 85). It was not taken at any ocean station from January through early April. Maximum density of this "estuarine and marine" species in the bays ($128,689/m^3$) occurred in July. Excluding the Inlet station, A. tonsa constituted 90% of the average copepod density in the bays during July. In the vicinity of the Site, densities were greatest ($15,000/m^3$) in late June and late September.

The density of A. tonsa decreased with distance from shore in the transect across the Site. At ocean stations north and offshore of the study area, densities did not exceed $3,000/m^3$, and it was never found offshore of Brant Beach.

Average monthly densities of A. tonsa at the Site exceeded $1,000/m^3$ two months earlier than in 1973. Maximum densities in 1973 and 1974 ($12,453/m^3$ and $5,725/m^3$) were noted in September.

Centropages hamatus, a "euryhaline marine" form which generally occurs within 20 miles of shore (Van Engel and Tan 1965), was common in the study area during spring and early summer (Table 86). It was absent from the Mullica River and scarce at the inner Bay stations (Great Bay #2 and Great Bay #3). It was taken at all ocean stations and was more abundant at the Site in 1974 than in 1973.

Centropages typicus, a "stenohaline marine" form, has not been a significant component of the zooplankton in this study to date. It was generally more abundant and occurred most frequently at the stations north and offshore of the study area (Table 87). It was a dominant form off Delaware Bay (Deevey 1960) and in the New York Bight (National Marine Fisheries Service 1972).

Oithona brevicornis, an "estuarine and marine" form, was taken year-round in the ocean and bays; slightly higher densities were recorded from the bays (Table 88). Lowest densities coincided with minimum water temperatures. In both 1973 and 1974, maximum densities in the ocean were not obtained until after the breakdown of the thermocline during late summer. It was sparse at the station offshore of Brant Beach. Maximum density of this species ($10,220/m^3$) was substantially below that in 1973 ($62,518/m^3$).

Oithona similis, a "euryhaline marine" form, was the only species common at the Site throughout the year (Table 89). It was only occasionally common in the bays. Minimum densities in the bays and ocean were noted during the period of maximum water temperatures. Densities were greater in late fall of 1974 than in 1973 but were similar during other seasons.

Pseudodiaptomus coronatus, an "estuarine and marine" from, was collected at all stations except those offshore of the study area (Table 90). In the bays, its density exceeded $1,000/m^3$ at least once at all stations. In the ocean, it was usually common only at the Site and landward of the Site. It was generally uncommon at stations seaward of the Site and north of the study area. In 1974, it was common at the Site from June through September. In 1973, it was common only in November and it was generally absent the rest of the year.

Paracalanus crassirostris, an "estuarine and marine" form, was taken throughout the year. Ocean densities generally exceeded bay values although the maximum density ($28,647/m^3$) was obtained in Little Egg Inlet (Table 91). It was a dominant member of the copepod community from July through November. During 1973, it was dominant only in August and September.

Paracalanus parvus, a "euryhaline marine" form, occurred almost exclusively at ocean stations, and primarily in late summer and fall (Table 92). Maximum density was $7,565/m^3$ in 1974 and $1,180/m^3$ in 1973.

Of the above two species, P. parvus dominated in the New York Bight (National Marine Fisheries Service 1972) and P. crassirostris predominated in this study.

Pseudocalanus minutus, a "euryhaline marine" copepod, was a dominant form during winter and spring (Table 93). Its occurrence in the study area during the summer was dependent on the presence of a marked thermocline. With a warming of the water column, this species virtually disappeared. In early August, it was taken in oblique tows only at stations offshore of the study area, although it was present at the Site in a bottom collection. It was more abundant at the Site in 1974 than in 1973. It is a major copepod over the inner continental shelf off Chesapeake Bay (Van Engel and Tan 1965). In the New York Bight, it was found year-round and was considered the most important copepod for fish feeding on zoopanktkon (National Marine Fisheries Service 1972).

Temora longicornis, a "euryhaline marine" form, was taken in all months but was common from February through early August in the ocean and from March through May in the bays. It was rare or absent during the period of maximum water temperature. Its occurrence and distribution paralleled closely that of P. minutus (see Tables 93 and 94). Largest densities were found at stations north and offshore of the study area. However, Jeffries (1967) reported that it was more common in estuarine than in shelf waters.

Harpacticoids were collected throughout the year at all stations (Table 95). Their densities were fairly constant throughout the bays from April through October; maximum density was 5,100/m^3 in May. In the ocean, they were uncommon through early August. From late September through November, densities at the Site usually exceeded 15,000/m^3. Examination of day/night collections indicated no obvious vertical migration or stratification of these forms despite their generally benthic habit. In 1973, densities at the Site did not exceed 1,000/m^3.

Other Holoplankton

Most organisms of the group "other holoplankters" were more prevalent in the ocean than in the bays. No significant difference in density was found between ocean stations, but densities were generally greater for the year at the Brant Beach stations (Fig. 31). Differences between bay stations were significant and greatest densities were at higher salinities (L. E. Inlet and L. E. H. #2). At the Site, they were most abundant in May, predominately Fritillaria sp., and from August through October, predominately Penilia avirostris and Oikopleura spp.

The dinoflagellate, Noctiluca scintillans, was dominant from late August to early November. It was more prevalent at the inshore stations; a maximum density (102,857/m^3) was observed at the Site in September (Table 96). It can be a causative agent of red tides (Fung and Trott 1973).

Four species of cladocerans were collected. Penilia avirostris, Podon polyphemoides and Evadne nordmanni predominated; Podon leuckarti occurred only occasionally and in low densities.

Only P. avirostris, a "euryhaline marine" form (Della Croce 1966), occurred in sufficient number and frequency to determine its distribution in the study area (Table 97). On 30 August, it was common at the Site and the seaward station but it was not found at the landward one. Collections that day were taken on an ebbing tide. It showed a similar pattern of occurrence and abundance in 1973 and 1974.

Podon polyphemoides was rare in 1974 but abundant in 1973. E. nordmanni occurred only occasionally in both years.

Oikopleura spp. (primarily O. dioica) were the most abundant appendicularians and occurred mainly from July through November. Appendicularians are primarily offshore inhabitants. Although O. dioica is tolerant of salinities as low as 12 ppt (Gosner 1971), it was scarce at bay stations. Largest densities were usually at ocean stations north and offshore of the study area (Table 98). Little difference occurred between densities at the Site in 1973 and 1974.

Meroplankton

Bivalve larvae were collected year-round in the study area. In the bays they were only occasionally common (Table 99). The low densities in the bays appeared anomolous in view of the large populations of Mercenaria mercenaria, Modiolus demissus, Aequipecten irradians and Tellina spp. which were present. Carriker (1961) reported densities of up to 67,000/m^3 of M. mercenaria larvae in Little Egg Harbor, although within 3 days, densities fell to below 100/m^3 due to predation and tidal flushing.

Densities of bivalve larvae at the Site above 5,000/m^3 were found mainly in May, October, and November (Table 99). In 1973, densities usually exceeded 5,000/m^3 from June through October. The dominant form in May, July, and November 1973 was Ensis directus, Spisula solidissima, and Modiolus demissus, respectively (Table 100). Identification of bivalve larvae to species is difficult and has not been done yet for 1974 collections.

Gastropod larvae were most abundant from May through September. The maximum density in the bays (37,660/m^3) was noted in early July in the Mullica River. In the ocean, the maximum density (10,074/m^3) during daylight collections occurred in late July at the station landward of the Site. At night, a maximum surface density of 150,426/m^3 was found at the Site in June. Larvae of the marsh snail, Melampus bidentatus, were dominant ($>$90%), and it was one of the most abundant taxa taken in any collection during this study.

Polychaete larvae were collected year-round (Table 101). In the bays, they were common to abundant from April through early November. At ocean stations, greatest densities generally occurred in the vicinity of the Site. The larvae of Polydora sp. was usually dominant in spring and early summer. Large numbers of swarming "clam worms" (epitokes of *Nereis* sp.) were observed during July and August.

Echinoderm larvae were found only in ocean and inlet samples; maximum densities occurred in early July (4,266/m^3) in 1973 and in late August (2,717/m^3) in 1974. Densities of post-larval starfish taken in ponar collections in July were approximately 400/m^2 in 1973 and 15/m^2 in 1974.

Macrozooplankton

A total of 115 samples was examined from the Site in 1974 (Appendix Table 36). From three additional stations located north and offshore of the study area, 38 samples were examined (Appendix Tables 37 to 39).

Hydromedusae

A total of 14 species of hydromedusae was identified. *Liriope* sp. was the most abundant form at the Site, and was found from August through November. The highest density (356/m^3) was taken in a bottom tow in October. At stations north and offshore of the study area it was common (10-100/m^3) only during fall, but was less numerous there than at the Site. *Obelia* spp. were present ($<$10/m^3) during the first half of 1974 and were most common in March. *Rathkea octopunctata*, a small anthomedusae, occurred from January through July at the Site; it was most numerous (38/m^3) in May. Other winter-spring species included *Margelopsis gibbesi*, *Sarsia* spp., and *Podocoryne* sp.. Species collected in the summer and fall were *Bougainvillia* spp., *Phialidium* sp., *Aequorea* sp., *Blackfordia* sp., and *Amphinema* sp..

Chaetognaths

Arrow worms were collected throughout the year at ocean stations. Sagitta elegans, a cold water species, was common from January through July especially in daytime bottom collections at the Site. It was the dominant macroplankter during the winter and early spring when maximum densities of 345/m^3 (January) and 170/m^3 (April) were taken in bottom tows. Offshore of Brant Beach, it was common in March and from May through November (no collections were taken in January, February, April, and December); maximum densities were observed in September (92/m^3) and October (71/m^3) (Table 102). Its disappearence from the Site in July and the increase in densities offshore in September and October may indicate that S. elegans leaves the nearshore areas during the summer. Bigelow and Sears (1939) reported a similar distribution outside of Delaware Bay during the summer.

Sagitta enflata, a warm water species, occurred from August through November at all ocean stations. It was most numerous (34/m^3) offshore of Little Egg Inlet in November. Another warm water species, S. serratodentata, was taken offshore of Brant Beach in August.

Sagitta tenuis was present in October and November at both offshore stations. It had not previously been reported north of Delaware Bay (Grant 1963).

Tunicates

Doliolids and salps are considered open ocean forms, although appreciable numbers may be found in coastal waters (Gosner 1971). A doliolid, Doliolum nationalis, was most abundant from August through October at the two offshore stations. The greatest concentration ($178/m^3$) was taken offshore of Brant Beach in October. A salp, Thalia democratica, was abundant in August at all ocean stations except the Site and was found at densities of up to $416/m^3$ offshore of Brant Beach.

Mysids

Neomysis americana was taken in small numbers throughout the year at the Site; however, one bottom collection in July yielded $1,546/m^3$. At stations north and offshore of the study area, it was present in March and from May through September. Day/night samples showed that it was most numerous in bottom collections during the day. Two to four hours after sunset, large numbers were collected in surface waters (Table 103).

Mysidopsis bigelowi, a warm water mysid, was occasionally found in the spring and fall at ocean stations. The greatest density ($44/m^3$) was taken in a night bottom collection from the Site in October.

Shrimp Larvae

Zoeal stages of the sand shrimp, Crangon septemspinosa, were collected throughout most of the year at ocean stations. At the Site, larvae were common in late spring; the greatest density ($69/m^3$) was taken in May in a bottom tow. During August and early September, 1974, larvae were absent (Table 104). During this period in 1973, a maximum density of $312/m^3$ (bottom) was collected. However, the bottom water temperature at the time of collection was considerably colder than usual. Larvae were common at the station off Brant Beach in June ($20/m^3$) and at the two offshore stations in July ($22/m^3$, $27/m^3$).

Zoeae of the grass shrimp, Palaemonetes spp., were common at the Site from June through September and were most abundant ($265/m^3$, bottom) in July. They were scarce north and offshore of the study area. During the day, zoeae were more numerous in bottom tows (93% of those taken) than at the surface. At night, zoeae were more evenly distributed throughout the water column and in general, were caught in greater densities than during the day (Table 105).

Zoeae of three species of mud shrimp were occasionally taken in the ocean. Upogebia sp. zoeae were present from June through September at the Site but were absent from the offshore stations. Zoeae of Naushonia crangonoides were present at the Site in June and offshore of Little Egg Inlet in July. Callianassa sp. zoeae were present off Brant Beach in August and at the Site in September.

Zoeal stages of Lucifer faxoni, an oceanic shrimp, were present from August through October at ocean stations.

Crab Larvae

Crab larvae occurred at the Site from March through November and comprised most of the macrozooplankton from June through August. During the day, they were most numerous in bottom samples, but after dark they were concentrated near the surface. Densities were generally lower at the stations north and offshore of the study area; here the larvae of hermit crabs, fiddler crabs, and mud crabs were sparse (Table 106).

Zoeae of the rock crab, _Cancer irroratus_, were taken at the Site from March through June and reached a maximum density of $8/m^3$ in early May. Megalopae were collected in June, July, and September. At the stations north and offshore of the study area, zoeae were collected from March through July but were most common ($19-33/m^3$) in June. Megalopae were taken throughout the summer but were most numerous ($11-18/m^3$) in June (Table 107).

Zoeae of the blue crab, _Callinectes_ sp., were occasionally taken in June, July, and September at the Site. During the day, zoeae were taken throughout the water column, but at night all were taken at the surface. The maximum density of $21/m^3$ was taken at night in July. Megalopae were present from August through October at the Site and were most common ($8/m^3$) in September. At stations north and offshore of the study area, zoeae and megalopae were also present from June through October; megalopae were more numerous than at the Site (Table 108). Tagatz (1968, cited by Sandifer 1972) concluded that development after the second zoeal stage takes place offshore and the larvae return inshore as megalopae.

Zoeae of the lady crab, _Ovalipes ocellatus_, were taken from June through October at all ocean stations. They were most common ($32/m^3$) at the Site in July and August (Table 109).

Zoeae of the spider crab, _Libinia_ spp., were collected from June through October but were most common ($97/m^3$ night, bottom) in July. They were usually more numerous in bottom tows. Megalopae were found in July, August, and October. At the stations north and offshore of the study area, larvae were scarce (Table 110).

Mud crab (Xanthidae) zoeae were taken at the Site from June through October. The greatest density ($38/m^3$) occurred in August. At the stations north and offshore of the study area, larvae were either scarce or absent (Table 111).

Fiddler crab larvae, *Uca* spp., were taken from June through August at the Site. The greatest density ($218/m^3$) was collected in a surface tow at night in July. They were scarce at the stations north and offshore of the study area (Table 112).

Zoeae of *Dissodactylus mellitae*, a crab commensal with the sand dollar, were collected in June and July at the Site. Zoeae of *Pinnixa* sp. (commensal with tube worms) were present from June through September and were most numerous in bottom tows. Larvae of another commensal, *Pinnotheres* sp., were noted in August from collections at the Site and north of the study area.

Hermit crab larvae, *Pagurus* spp., were collected from May through October and were the most abundant macroplankton species by number and frequency of occurrence at the Site. Concentrations of larvae up to $580/m^3$ were taken in bottom tows in July. During the day, 99% of the zoeae were collected near the bottom. Two hours after dark, most zoeae (74%) were taken in surface collections. Glaucothoe were present in July and August at the Site. At the stations north and offshore of the study area, hermit crab larvae were generally scarce (Table 113).

Zoeae of the mole crab, *Emerita talpoida*, were present from June through November at the Site and were most common in bottom samples. The highest density ($171/m^3$) occurred in September in a night sample; however, densities were usually less than $5/m^3$. Larvae were also scarce at the other ocean stations (Table 114).

Occurrence and peak abundance of selected macroplankters collected at the Site are summarized in Table 115.

Other Forms

Young specimens (< 12 mm) of squid (Loliginidae) were collected from June through October at ocean stations. They were most numerous in September and October at the two stations offshore of the study area where the greatest density was $0.85/m^3$.

Recently-hatched young of the horseshoe crab, Limulus polyphemus, were found only at the Site and only in July.

Pseudozoeae of a stomatopod, Squilla sp., were taken during the fall at ocean stations.

Hyperiidean amphipods (Hyperia galba, Hyperoides longipes, and Parathimisto gaudichaudi) were collected during the fall at ocean stations (Table 115). They are oceanic and some are parasitic on jellyfish. In October, they were most common $(88/m^3)$ offshore of Brant Beach. Other amphipods collected commonly included Gammarus annulatus, Cerapus tubularis, Microprotopus raneyi, Unciola irrorata, and Corophium tuberculatum.

Late stages of polychaete larvae were collected throughout the year but were most common $(68/m^3)$ in bottom samples in October. The pelagic polychaete, Tomopteris helgolandica, appeared at irregular intervals throughout the year. It was most numerous in August, 8 miles offshore of Little Egg Inlet.

Three species of pteropods and the heteropod, Pterotrachea sp., were found only north and offshore of the study area in the fall. They are primarily warm water, oceanic forms.

Siphonophores are also warm water, oceanic forms and were present in the fall at all ocean stations.

The ctenophore, *Beroe ovata*, was present during the fall at all ocean stations and was most numerous at the Site ($3/m^3$) in September.

Vertical Migration

Diurnal migration of zooplankton generally showed the same pattern in 1974 as in 1973. Zooplankton concentrations were generally greatest near the bottom from February through August and meroplankton usually exhibited the most pronounced daytime vertical stratification. In the other months, daytime stratification did not generally occur.

As in 1973, zooplankton densities from oblique tows usually exceeded the average densities of the surface and bottom values, indicating that most forms concentrated at some intermediate depth.

Distribution of Zooplankton

Holoplankton

Three general distribution patterns of copepods and other holoplankton were observed in ocean and bay collections. First, densities of "estuarine and marine" forms were similar at the Site and bay stations; these forms were less numerous or absent from stations north and offshore of the study area (Tables 84, 85, 88, 90, and 91). Second, "euryhaline and marine" forms were more abundant at ocean stations and densities were similar between these stations (Tables 86, 89, 92, 93, and 94). However, there was a trend for the cold water forms to show greater densities in early summer at the stations north and offshore of the study area (Tables 89, 93 and 94). Third, "stenohaline marine" forms were taken in greatest densities north and offshore of the study area and were usually absent or rare at bay stations (Tables 87, 97, and 98). These data are shown for copepods in Fig. 32.

Meroplankton

Densities of bivalve larvae in the ocean usually exceeded those in the bay by a factor of from 2 to 10 times (Table 99). Because early larval stages of many estuarine bivalves are either distributed throughout the water column or concentrated in surface waters (Carriker 1961, Thorson 1950), they are subject to tidal flushing and thereby contribute to the meroplankton found in the inshore ocean. Data from 1973 showed that the larvae of estuarine bivalves were at times common at the Site (Table 100). No significant difference in densities of bivalve larvae was found between ocean stations, but the yearly average for these forms was lowest off Brant Beach. Species density differences might have been found between stations if all the larvae had been identified.

Gastropod larvae occasionally were abundant in the bays and in the vicinity of the Site. On 20 June and 22 July, they were common to abundant at the Site and landward of the Site, but were present only occasionally or were absent seaward of the Ridge. During night sampling at the Site on 20 June, surface densities of gastropod larvae ranged from almost 0 at sunset to 150,426/m^3 later at night and on 22 July, from 5,104 to 39,205/m^3. Oblique tows and bottom collections showed little or no increase in density from sunset to later at night (Table 116).

Early larval stages of the marsh snail, Melampus bidentatus, were dominant (>90%) in these collections, indicating rapid tidal flushing from the marshes.

Organisms classified as gastropod larvae were common at the two offshore stations on two different dates. This may be due to counts of small, shelled pteropods which were not separated from gastropod larvae. Data on larger-sized pteropods from Bongo collections showed that these forms occurred only north and offshore of the study area.

Carriker (1967) stated that variations in the rate of tidal exchange may be the most critical factor in the retention of larvae within an estuary. He found that the tidal exchange of Little Egg Harbor varied from 20 to 47%; when the exchange rate was high, many hard clam larvae were lost from the bay. Tidal flushing may be responsible for the low densities of some meroplanktonic forms found in the bays during the present study.

Larvae which have been flushed from an estuary may return or be replaced. The benthic populations of some estuaries are dependent upon the transport of larvae from another estuary (Ayers 1956).

Macrozooplankton

Forty-six species of macrozooplankton were classified as either estuarine or oceanic (Table 117). Estuarine species included "estuarine and marine" and "euryhaline marine" forms; "stenohaline marine" species were classified as "oceanic". The two groups were expressed as a percentage of the total density for each collection taken monthly at the four ocean stations (Fig. 33). The number of oceanic and estuarine species present in every month was also determined for these stations (Fig. 34).

At the Site, the number of estuarine species exceeded that of oceanic species in every month. However, densities (n/m^3) of oceanic forms were greater than those of estuarine forms during the spring and fall. In the spring, Sagitta elegans and the larvae of Cancer irroratus were the most abundant oceanic forms. Estuarine species comprised most of the macroplankton in June (97%), July (100%), and August (66%) when crab and shrimp larvae were abundant. In late summer and early fall, warm water, oceanic forms such as siphonophores, arrow worms (Sagitta enflata), and hydromedusae (Liriope sp.) predominated.

Estuarine species which were present at the Site but scarce or absent at other ocean stations included larvae of Palaemonetes spp., Callianassa sp., Naushonia crangonoides, Emerita talpoida, Pagurus spp., Uca spp., Libinia spp., Limulus polyphemus, and xanthid crabs.

At the inshore station off Brant Beach, the number of estuarine species also exceeded oceanic species except in October and November. However, densities of oceanic forms were greater than those of estuarine species in every month but July when shrimp and crab larvae were common.

The two stations offshore of the study area were oceanic in character. Offshore of Little Egg Inlet, oceanic species outnumbered estuarine species except during July, August, and September. Densities of estuarine forms were low ($<17\%$ of the total number collected) in every month but July when they comprised 45% of the zooplankton. Offshore of Brant Beach, estuarine species outnumbered oceanic forms only in July but their densities were negligible.

Oceanic species present at the two offshore stations which were scarce or absent at the Site included pteropods, heteropods, Doliolum nationalis, Thalia democratica, Tomopteris helgolandica, and Hyperiidean amphipods.

These data indicate that during the summer, the Site is an area where the spawning and development of many estuarine species, particularly crab and shrimp, occurs. The large number of species yet small densities of estuarine forms present at the offshore stations during the summer, indicate that most arrive offshore as strays. Most of the macroplankton there is composed of oceanic species.

GLOSSARY

Abbreviations

f - frequency of occurrence; the number of times a species occurred in collections

n/b - number of fish caught by sport fishermen per boat

n/coll. - number of specimens per collection

n/f - number of specimens per collection in which the species occurred

n/h - number of fish caught per angler hour

n/t - number of fish caught per angler trip

Adults - those individuals that are sexually mature

Catch frequency - the percentage of collections in which a species was taken (frequency of occurrence/number of collections)

Charter boat - a boat and captain hired by a party of fishermen, usually on a daily basis

Demersal - refers to fishes found on or near the bottom

Epitokes - sexually ripe, free swimming form of the atokes of some polychaete families

Estuarine and Marine - zooplankters which propogate in estuarine and coastal (inner) neritic waters

Euryhaline marine - zooplankters which are found in estuaries but whose maintenance there is dependent on a continuous supply from the ocean

Glaucothoe - post-larval stage of hermit crabs (Paguridae)

Infauna - invertebrates which burrow into the bottom substrate

Juvenile - a stage in the life of a fish which starts when the body form first approximates that of the adult and terminates with attainment of sexual maturity

Macroinvertebrate - an invertebrate which is retained in a 1-mm mesh net

Neritic - water over the continental shelf

North and offshore of the study area - inshore off Brant Beach, approximately 10 miles north of the Site; approximately 8 miles offshore of Brant Beach; and about 8 miles offshore of Little Egg Inlet.

Notochord length - the distance "from the anterior edge of the head or tip of the snout to the tip of the notochord" (Smith and Fahay 1970)

Outlier - a value that is anomalously far from the regression line

Ovigerous - egg bearing, gravid

Pelagic - fishes which are distributed in the water column; inhabiting the open ocean

Phi (Ø) - a geological term which indicates particle size; the negative log of the grain size in mm

Phi size finder - a block of plastic inlayed with samples of sand in 1/2 Ø intervals from 0.0 to 4.0 Ø

Private boat - boats which are owned by individual fishermen

Seasonal classifications - these are based on water temperature and are as follows: winter (January-March), spring (April-June), summer (July-September), and fall (October-December).

Semidemersal - fishes found near the bottom and occasionally higher in the water column

Site - the area encompassed by the breakwater and plants (39°28'20" N latitude and 74°15'20" W longitude)

Stenohaline - zooplankters which characterize open (outer) neritic waters; they occur only infrequently near the mouths of estuaries

Study area - an area which includes the ocean in the vicinity of the proposed Site of the Atlantic Generating Station (AGS) and in the bays, rivers, and waterways from Manahawkin Causeway, Long Beach Island, to Atlantic City.

U-Drive boat - boat rented by a party of fishermen from a local marina

Vicinity of the Site - an area of the ocean from Holgate, Long Beach Island to off Brigantine Inlet and from the beach to approximately 6 miles from shore

Warp - rope or line used to tow a net

Young - fishes which are young-of-the-year (0+ year class)

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